Development And Validation Of Depth Inversion Algorithms For Barred-Beaches Based On Nonlinear Properties Of Shoaling Waves

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LONG-TERM

The long-term goal of this work is to develop methods for predicting the bottom topography in nearshore regions, based on characteristics of (shoaling) surface waves, measured using remote sensing methods. We are particularly interested in the surfzone region, over barred-beaches, where large wave nonlinearity and breaking occur.

OBJECTIVES

Earlier work dealt with monotonous topographies and periodic non-breaking waves (Grilli, 1997, 1998). In this work, the objectives are to :

(1) calculate and analyze fully-nonlinear periodic wave shoaling over barred-beaches in a two-dimensional Potential Flow Model (PFM).

(2) implement and calibrate a spilling breaker model in the PFM shoaling region, and accurately model breaking waves in the surfzone.

(3) compute shoaling of both non-breaking and breaking mildly irregular waves (with narrow-banded spectra), over barred-beaches.

(4) modify/extend earlier depth-inversion-algorithms (DIA) to predict depth in the region over and beyond the bar, based on (measurable) global wave characteristics.

(5) improve the model computational efficiency for large-size/long-term computations.

(6) validate both shoaling calculations and depth predictions using field data (possibly from Duck (SHOWEX); John Dugan's measurements).

APPROACH

In earlier work, DIAs were developed for cylindrical beaches (Grilli, 1997, 1998). These were based on inverting a nonlinear wave celerity relationship, obtained from results of direct shoaling computations in a fully-nonlinear PFM. Since the nonlinear celerity also depends on wave steepness,

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wave height or front-to-back asymmetry data was also required, in addition to wave phases, to perform depth inversion.

A similar approach is pursued in this effort. The PFM will first be extended to deal with barred-beaches and non-periodic, possibly breaking, incident waves. Direct problems will first be calculated and a parametric study of wave characteristics in the region beyond the bar will be performed. Modifications/extensions of DIAs will be made, based on these results. Shoaling calculations and depth predictions will be validated using field data.

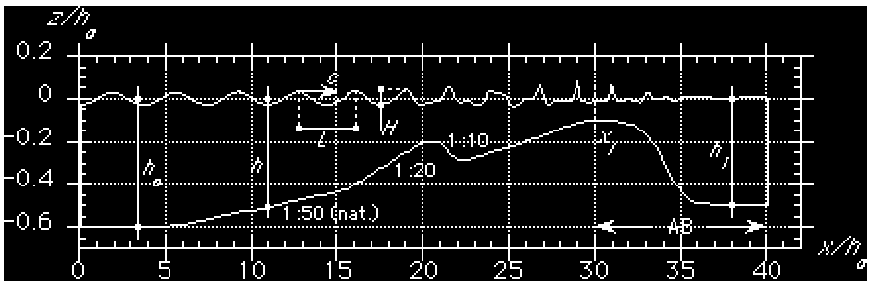

Figure 1 : PFM computations for the shoaling of periodic waves over a barred-beach with equilibrium shape (1:50 average slope). Definition of global wave parameters (H, L, c). AB : absorbing beach. Note the wave decomposition region beyond the bar.

WORK COMPLETED

Direct computations and analyses of periodic waves, shoaling over barred-beaches, were performed in a two-dimensional PFM (Grilli and Horrillo, 1999; e.g., Fig. 1). DIAs developed earlier for monotonous topographies were applied, and discrepancies in depth prediction were observed in the region beyond the bar; analyses showed, these are due to wave decomposition phenomena occurring in this region (Grilli and Skourup, 1999).

Groundwork was done for the implementation of a spilling breaker model in the shoaling region of the potential model. This model is based on specifying an absorbing surface pressure (Grilli and Horrillo, 1997), whose work is calibrated with the energy dissipation obtained from a semi-empirical spilling breaker model.

A Volume Of Fluid (VOF) model, solving Navier-Stokes equations, was applied to the modeling of breaking surfzone waves. The VOF model was coupled to the PFM used in the shoaling zone (Guignard et al., 1999; e.g., Fig. 2). Preliminary results show good agreement with laboratory data (Guignard et al., 2000).

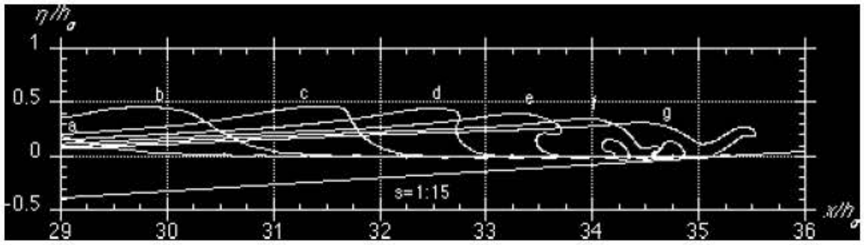

Figure 2 : Coupled PFM/VOF computations for the shoaling and breaking of a solitary wave over a plane 1:15 beach. Curves a-g denote successive times.

In a parallel, independently supported, work, a three-dimensional fully nonlinear PFM, applicable to arbitrary bottom topography, was developed (Grilli et al., 1999; e.g., Fig. 3). This model could be used to estimate effects induced on shoaling waves by three-dimen- sional topographic features, as compared to two-dimensional results.

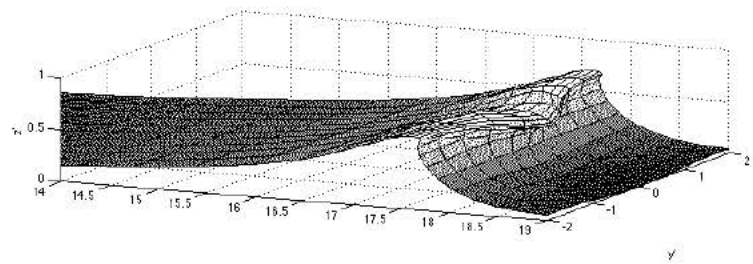

Figure 3 :Three-dimensional PFM computations for the shoaling and breaking of a solitary wave over a plane 1:15 beach with a middle ridge.

Contacts were made with John Dugan (Arete Assoc.) who will conduct field experiments at Duck (SHOWEX), using airplane based sensors. A comparison of depth prediction using linear wave theory based and nonlinear DIAs will be made using his data.

RESULTS

Preliminary PFM computations for a barred-beach identify the need for refining DIAs in the wave modulation region beyond the bar. Computed wave front and back slope variations in this region show that wave slopes, which are obtainable from remotely sensed surface observations, may help identifying bar topographic features.

The coupled two-dimensional PFM/VOF model provides a fully nonlinear solution for wave shoaling from deep water, up to breaking in the surfzone. Breakers are well modeled by the VOF solution of Navier-Stokes equations, which also includes modeling of the air flow above the free surface, and of air pockets trapped in the water. The coupled model will make it possible to accurately calculate nonlinear wave parameter variations (celerity, height, wavelength, asymmetry), from deep water up to runup on the shore.

IMPACT/APPLICATIONS

The two- and three-dimensional models refined and developed as part of this work constitute robust and flexible nonlinear wave modeling tools, applicable to a variety of ocean and coastal engineering problems. The models were developed as so-called “numerical wave tanks”, in which many types of boundary conditions and geometry can be easily specified. In particular, it would be easy to include fixed or floating structures in the models, and to calculate wave-structure interactions. The models were based on a higher-order Boundary Element Method, which is both efficient and accurate. For more efficiency, the two-dimensional coupled model works on a bi-processor computer (Guignard et al., 2000), and the three-dimensional model has been optimized for use on a CRAY-90 multi-vector processors (Grilli et al., 2000).

TRANSITIONS

The two- and three-dimensional modeling work performed in this project is closely related to other (collaborative) wave modeling efforts the PI is involved with : (i) the generation and coastal runup of tsunamis, due to underwater landslides (Grilli and Watts, 1999); (ii) the modeling of three-dimensional breaking waves over various coastal topographies, and the study of their kinematics (Grilli et al., 2000); (iii) the three-dimensional nonlinear wave focusing, as a possible mechanism for creating very large (freak) waves.

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